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SUBCOOLED BOILING IN A NEGLIGIBLE GRAVITY FIELD

Prepared for

National Aeronautics and Space Administration

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I. INTRODUCTION

This status report is the first on a research program sponsored by the National Aeronautics and Space Administration to investigate the characteristics of subcooled, nucleate boiling in a negligible gravity field. The objectives of the program are to examine the mechanism of bubble growth and collapse, and the net heat flux which results in a boiling subcooled fluid in the absence of gravity.

II. STATUS OF TECHNICAL WORK

Project efforts to date have been directed toward the design of experimental equipment, including drop tower and deceleration device, drag shield, instrumented test section and dummy drop package. Design of these items is discussed in detail below.

An unfortunate set-back has frustrated efforts to accomplish actual instrumented drops of the dummy capsule. A 120-foot high, 24-inch diameter tower enclosure was constructed of sections of specially treated cardboard tubing upon a steel tower structure in preparation for initial drop tests. Despite assurances of the vendor that the tubing would withstand the elements for many months, an extreme weathering condition quickly resulted, and the tower enclosure was dismantled as a safety measure before a package drop could be accomplished.

All support brackets and the suspension system provided for the above tube tower will be used in the construction of a steel tubing drop tube which is described in detail below. Steel tubing has been ordered, and will be delivered in approximately two weeks.

In the construction of the negligible gravity drop tube, structural support is provided by a tower 150 feet in height, 6 feet by 6 feet square. At the top, three overhanging platforms project outward approximately $4\frac{1}{2}$ feet from the tower. The lowest of these is 135 feet from the base.

The drop tube will be suspended from the second tier and will be supported by steel cables (two) extending the entire length of the tube. The tube itself is being made in 20-foot sections with a total length of 120 feet. The 16-gage galvanized steel tube will extend to within 15 feet of the ground.

A method of suspending the tubing which will allow maximum flexibility has been chosen, since the only external forces acting upon the tube are caused by wind loading, which is not a significant factor.

The tubing is 2 3/4 inches O.D.. Circular brackets with a rim welded on the inside diameter provide a support and alignment collar for each individual section of tubing. Each section has only to support its own weight (slightly less than 400 pounds). The brackets were constructed in such a manner that the top of each tube extends a short distance into the bottom of the bracket directly above it and, therefore, is contained both above and below. Clamps are provided on the brackets in order that they may be attached directly to the two supporting cables. The tube position is maintained exactly vertical through use of positioning braces located at both the top and bottom of the tube. To provide additional lateral support, the tubing is stabilized through use of three additional stability braces which tie the tube rigidly to the tower.

A small electric hoist is employed for transporting the drop package to the desired vertical position in the tube. The hoist capacity is 600 pounds, with 300 feet of 3/16-inch steel cable, and is powered by a 110 Volt A.C. motor with a positive action clutch. Final adjustment of the capsule position will be accomplished by deflection of the cable at ground level.

An instrumentation room has been provided at the base of the tower. Inside dimensions of the room allow a limited amount of storage space and also sufficient space in which to make necessary preparations for each drop.

Satisfactory deceleration of the drag shield and test specimen is of major importance. A deceleration device consisting of a cylindrical steel container 108 inches high and 32 inches in diameter will be utilized to contain the impact material. The weight of this container is approximately 400 pounds and is provided with a hinged door for accessibility. Also, the chamber has a weather-tight top to protect the deceleration device from the elements. An average deceleration of approximately 20 to 25 g.'s can be expected using spirally-wound cardboard as a deceleration material. The rate of deceleration may be controlled by varying the tightness with which the cardboard is wound.

Preliminary calculations indicate that nearly nine feet of deceleration material is necessary to bring the drop package to a complete stop since the ultimate velocity will be approximately 89 ft/sec. when dropped from a height of 120 feet.

A dummy capsule will be used to test drag effects of the drop tube, evaluate the deceleration device, and determine the best method of releasing the drop package. The dummy capsule is 61 inches in length and weighs 120 pounds. Construction of wood will allow maximum flexibility at minimum cost. The outside diameter is 12 inches, and the design provides a hemispherical nose and a conical tail section.

The drag shield which will contain the instrumented test section is designed in four basic elements. These are:

1. A central tubular portion approximately 3 1/2 feet in length. This section will be 12 inches in inside diameter with a 3/16-inch thick aluminum wall.
2. A hemispherical nose of 1/2-inch thick steel.
3. A tail section in the form of a truncated cone. This section will again be 3/16-inch thick aluminum with an overall length of approximately 12 inches.
4. A structural framework within the shield to give strength to the capsule and to support the necessary batteries and instrumentation components.

The outer sections will be assembled in such a way as to permit ready access to the inner package and instrumentation. Total drag shield weight will be approximately 80 pounds.

It is planned to suspend both the outer drag shield and the inner package by music wire, and to release both for free fall by severing the wires with an electrical discharge. Electrical energy will be discharged from a capacitor through a small section of the wires, and the inner wire will part first to provide the desired delay time between release of the two units. Experiments are being conducted to establish energy and delay time requirements.

Design of the instrumented inner drop package has been directed toward the elimination of two major deleterious effects which could negate any data obtained during drop. These problems are:

1. The residual convection currents which exist in a preheated boiling fluid, and
2. The maintenance of focus in the film plane with the test section moving away from the camera.

In order to proceed to the first objective, it was deemed desirable to establish the requirements and techniques for the generation and delivery of steam to an orifice in the bottom of the test cell to produce artificial boiling bubbles. The necessary information was obtained by constructing a model including steam generator, valves and test cell. The information gained from the model served as a basis for design of a simplified system for steam generation and delivery.

The second objective, the maintenance of a crisp image of the bubbles while the test cell is moving relative to the camera, was attained

using the concept of infinite focus for the camera. By employing a lens system in the test cell which focuses the bubble image at infinity, while the camera itself is focused at infinity, the resulting photographs will have the necessary resolution even though the object distance is changing during the drop.

The inner package will contain appropriate thermocouples to measure the temperature of both the steam and the water in the test cell.

III. FORECAST

Culmination of the overall tower design and construction phases is expected to be accomplished in approximately three weeks. Completion of the tower will then permit gathering of the data required for final establishment of drag shield length.

It is anticipated that the drag shield and partially instrumented package can be subjected to drop tests in December, and that fully instrumented data drops will take place in January.

The initial study efforts will be directed toward investigation of the growth and collapse of artificially created vapor bubbles in a subcooled bulk liquid. Subsequent research will be conducted on the more general question of the prediction of heat fluxes in a subcooled, nucleate boiling system in the absence of gravity.